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SUSTAINING MEMBERS

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CONTROL OF FUSARIUM DRY ROT OF POTATOES BY SEED TREATMENT[1]

G. W. Ayers[2] and D. B. Robinson[2]

Introduction

Serious losses in stored potatoes are incurred yearly in temperate countries due to infection by tuber-rotting Fusaria which enter the tubers through wounds contracted during harvesting and subsequent handling of the crop. In Canada, the Northern United States and Great Britain most decay of this type is caused by the two species *Fusarium sambucinum* f6 Wr. and *Fusarium coeruleum* (Lib.) Sacc. (2, 3, 4).

Attempts have been made to control dry rot by chemical treatment applied to the tubers at harvest time and some success in controlling decay caused by *F. coeruleum* has been achieved by dusting tubers with "aretan" and "fusarex" (1, 5). In Prince Edward Island "fusarex" was tested and proved ineffective as a protectant against infection caused by *F. sambucinum* f6.

Dry rot of harvested tubers originates from inoculum present in the soil but the importance of introducing such inoculum into soil as spores or mycelium on the seed-piece surfaces has not been previously assessed. This paper presents evidence of the importance of such seed-borne inoculum on the occurrence of two Fusarium rots and the value of seed treatment as a control.

Materials and Methods

Parallel trials were carried out with the two dry rot pathogens *F. sambucinum* f6 and *F. coeruleum*. Infection with the former was studied in the variety Sebago and with the latter in the variety Keswick, these varieties being chosen because of known susceptibility to dry rot.

The degree of infestation present on the seed stock used was not estimated but heavy surface contamination was assured in certain lots by immersing tubers in concentrated spore suspensions before planting. Half of the untreated and/or artificially inoculated seed was treated with the organic mercury fungicide "Semesan Bel" before being cut and planted. All treatments were in replicate and care was exercised in planting so that no transference of inoculum occurred between treatments.

The experiments were located on land where adjacent potato plantings showed no more than a trace of rot in the harvested crop despite severe handling at time of harvest. It is therefore assumed that very little dry rot inoculum was present in soil chosen for experimental use and that any such inoculum present had little influence on the degree of infection occurring in the harvested crop.

The tubers produced in the experimental plots were harvested with an elevator digger, then severely bruised by being dropped on a specially designed platform.

Records on percentages of tubers showing dry rot were obtained after four or five months storage at 40-44°F.

[1]Accepted for publication August 12, 1955.
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Experimental Procedures and Results

1951-1952 Trial

In a limited preliminary trial Sebago and Keswick seed was selected from lots in which storage rot had been severe and half of the seed tubers were treated with Semesan Bel. The treated and untreated tubers were then cut into seed pieces and planted in replicates of four. Forty tubers were harvested in each replicate and the development of dry rot is shown in table 1. Tuber stock grown from seed treated with Semesan Bel showed less storage rot than stocks from untreated seed but differences encountered were not significant. Further experimentation was planned using more replicates and greater numbers of tubers.

1952-1953 Trial

Inoculated lots of seed pieces and lots receiving no treatment other than immersion in Semesan Bel were planted in six-replicated plots of 50 plants each. Tubers were harvested in mid-October and examined four months later. The results, given in table 2, show a significant reduction in dry rot where the seed was treated as compared to the crop from seed immersed in spores before being planted.

1954-1955 Trial

In this trial seed tubers of each of the Keswick and Sebago varieties were divided into four lots. One series was untreated; a second series was treated with Semesan Bel; a third series was dipped in heavy spore suspensions and then treated with Semesan Bel. The seed was then planted in eight-replicated tests in which each plot consisted of 30 plants. Tubers were harvested in mid-October and the March 1955 readings are summarized in tables 3 and 4. The results given in table 3A show a reduced incidence of rot in Sebago tubers produced from chemically treated seed as compared with those produced from seed immersed in a spore suspension before being planted. Keswick tubers from seed treated with Semesan Bel showed a very significant reduction in decay when compared with stock produced from untreated seed or that dipped in a spore suspension of *F. coeruleum* (Table 3B). Results of the Keswick test differed from those preceding in that the two Fusaria under study were found associated with decay. Individual lesions were classified for symptoms and the percentage rot caused by each organism is recorded in table 4. Results show a high measure of control of both types of rot through chemical seed treatment of untreated and inoculated seed.

Discussion

Experiments conducted over a three-year period clearly show that a high measure of dry rot control in tuber progeny may be affected through an organic mercury treatment of seed tubers carrying heavy surface infestations of dry rot inoculum.

The low percentages of rot found in tubers produced from chemically treated seed were either due to infection by dry rot elements already present in the soil, or arose from developing inoculum introduced on the seed and not eliminated by seed treatment. It is considered that the small amounts of organic mercury present on the seed-pieces would exert little

TABLE 1.—*The effect of seed treatment on the occurrence of storage rot in harvested tubers.*

Variety	Seed Treatment	Tubers Examined	Percentage Rot
Sebago	Semesan Bel dip	160	1.9
	Untreated	160	6.3
Keswick	Semesan Bel dip	160	1.3
	Untreated	160	10.6

TABLE 2.—*Dry rot development in Sebago and Keswick tubers grown from chemically treated versus inoculated seed.*

Variety	Seed Treatment	Tubers Examined	Percentage Rot	Converted Percentages
Sebago	Semesan Bel dip	888	0.1	0.7
	Spore suspension dip[1]	558	1.9	6.7
L.S.D. at P = 0.05				5.64
Keswick	Semesan Bel dip	719	1.3	3.7
	Spore suspension dip[2]	983	5.5	13.3
L.S.D. at P = 0.05				5.62

[1]Conidial suspension of *F. sambucinum f6*
[2]Conidial suspension of *F. coeruleum*

soil fungicidal action except perhaps in the immediate proximity of the seed-pieces and not in the areas of tuber formation. On this basis the low infection encountered would indicate that dry rot inoculum was absent or present in limited amounts in land chosen for experimental use. The chemical seed treatment trials would therefore indicate that important infestations of potato land with dry rot Fusaria may occur through the introduction of inoculum on the seed piece surfaces. It is probable that much of the commercial seed planted carries such inoculum which may undergo development in the soil and later give rise to storage rot in the harvested crop. The extent of rot will depend on the susceptibility of the variety, the extent of mechanical injury, and the suitability of the soil as a medium for the seasonal development of the pathogens. In most of the tests conducted in connection with control by seed treatment an attempt was made to assure heavy spore contamination on the seed surfaces by immersion in concentrated suspensions of the pathogens. This procedure gave greater significance in favor of seed treatment except in an experiment conducted in 1954 using the variety Keswick. In this test immersion in spores resulted in a reduction in extent of decay in the harvested crop.

TABLE 3.—*The effect of seed inoculation and seed treatment on the occurrence of storage rot in tubers bruised at harvest time.*

A
Variety: Sebago

Seed Treatment	Tubers Examined	Percentage Rot	Converted Percentages
Spore suspension dip[1]	998	5.0	12.9
Untreated	1095	2.1	8.0
Spore suspension dip[1] + Semesan Bel dip	841	1.5	6.0
Semesan Bel dip	972	1.3	4.6
L.S.D. at P = 0.05			4.7

B
Variety: Keswick

Seed Treatment	Tubers Examined	Percentage Rot	Converted Percentages
Spore suspension dip[2]	843	18.7	25.0
Untreated	972	28.5	32.0
Spore suspension dip[2] + Semesan Bel dip	707	3.4	10.4
Semesan Bel dip	748	6.8	14.5
L.S.D. at P = 0.05			6.9

[1]Conidial suspension of *F. sambucinum* f6
[2]Conidial suspension of *F. coeruleum*

TABLE 4.—*Analysis of data in table 3B showing the degree of rot caused respectively by F. sambucinum f6 and F. coeruleum.*

Seed Treatment	Percentage Rot		Converted Percentages	
	F. sambucinum f6	*F. coeruleum*	*F. sambucinum* f6	*F. coeruleum*
Spore suspension dip[1]	9.3	9.5	17.2	16.9
Untreated	18.5	10.0	24.9	18.0
Spore suspension dip[1] + Semesan Bel dip	1.8	1.6	7.1	5.7
Semesan Bel dip	5.5	1.3	12.4	5.7
L.S.D. at P = 0.05			6.4	5.4

[1]Conidial suspension of *F. coeruleum*

thus indicating that the seed stock chosen was already heavily contaminated with dry rot inoculum.

Summary

A high degree of control of dry rot in stored potatoes has been obtained by a seed treatment of seed tubers at planting time. Evidence is given that the fungicide destroys much of the seed-borne inoculum that might otherwise develop in the soil and enter the new tubers through wounds contracted during harvesting and grading.

Literature Cited

1. Anon. 1948. Chemical prevention of potato dry rot disease. Nature (London) 162:843.
2. Cassell, R. C. 1945. Fusarium rots and storage diseases of potatoes in New York. Pl. Dis. Reptr. 29:337-342.
3. McKee, R. K. 1952. Dry rot diseases of the potato. II Fungi causing dry rot of seed potatoes in Britain. Ann. Appl. Biol. 29:38-43.
4. Robinson, D. B. and G. W. Ayers. 1953. Fusarium storage rot of potatoes in Prince Edward Island. Can. Jour. Agr. Sci. 33:566-571.
5. Small, T. 1946. Further studies on the effect of disinfecting and bruising seed potatoes on the incidence of dry rot (*Fusarium coeruleum* (Lib) Sacc.). Ann. Appl. Biol. 33:211-219.

STORAGE TESTS FOR THE CONTROL OF DISEASES AND INSECT PESTS[1]

H. C. Choudhuri[2]

No other agricultural crop possesses so wide an appeal throughout the world as the potato. In parts of the country where potatoes are produced on a commercial scale the problem of storage is important, as it is practically impossible as well as economically undesirable to attempt to market the entire crop just after it is harvested. To insure steady, uniform supply throughout the year, storage must be provided at a proper place. The types of storage places employed vary with the quality and quantity of potatoes stored and the length of the storage period.

Potatoes are cultivated as a commercial crop in West Bengal both in the hills and plains. The bulk of the potato acreage is in the plains. The climatic conditions in the plains are such that the minimum and maximum temperature ranges on the average from 80°-96° F. during the spring and summer months, from April to August. In this temperature range, the potatoes are subject to decay and deterioration during prolonged period of storage. It has been noted that during the storage period, decay caused by the tuber-moth (*Phthorimea operculella*) and dry rot (*Fusarium cerulеum*) which usually start just after harvest manifest themselves in storage causing serious damage to an extent of 50 per cent in the course of 8 months as noted by Mathur and Singh (6). Although Kapur, Mathur and Singh (3) reported that storage of potatoes in cold storage at a temperature range varying from 55°-38° F. with a relative humidity of 85-90 per cent is the most ideal method of storing potatoes, this facility, however, is beyond the reach of the ordinary farmers, as the refrigerated storages are very few in number and small in their capacities in comparison to requirement. It is therefore thought necessary to find out some sort of suitable treatments for tubers by which these can be stored in ordinary unrefrigerated storage fairly well at the usual temperature ranges of the spring and summer months.

Trials for the control of storage diseases have been conducted since the 1948 season. In the first season indigenous methods by treatment of potatoes with Margosa leaves (*Melia Azadirachta* Linn.), Garlic (*Allium sativum* Linn.) and Onion (*Allium cepa* Linn.) bulbs were found unsatisfactory as these treatments did not cut down the loss sufficiently; so these indigenous treatments were discontinued. Since 1949-1950 to 1951-1952 various fungicidal, insecticidal and sprout-inhibiting formulations have been used experimentally and have cut down loss significantly.

During the summer months, in June and July, in the humid hot weather these storage diseases become very destructive taking a heavy toll of stored potatoes. Under these conditions pretreatment of potatoes with Geigy-33A and Gammexane D.034 cut down the storage loss greatly as compared with other fungicides, insecticides and sprout-inhibiting formulations.

[1] Accepted for publication August 1, 1955.

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The experiments with Geigy-33A and Gammexane D.034 in comparison with other chemical formulations used during the three seasons, produced interesting results, which are recorded in this paper.

Materials and Methods

All trials were made with tubers of local Darjeeling Red Round variety. This variety does not seem to have good keeping quality and so it was used in these treatments to eliminate the factor of "good keeping quality". The potato tubers used were harvested after full maturity at the end of March in the plains. All potato tubers were treated on the same day, under similar conditions.

The fungicides, insecticides and sprout-inhibiting formulations were either dusted (after mixing with fine dust), or the tubers were dipped in a solution. The active ingredients of these fungicides *etc.* and details of the treatments are shown in table one.

In each treatment 40 pounds of potatoes were treated. The treated potatoes were kept on shelves at a depth of a single row of tubers in an unrefrigerated storehouse.

Experimental Data

Table 2 and figure 1 show the percentages of loss of potatoes caused by decay and total percentages of loss in weight due to physiological reasons. It is apparent from the table that the percentage of loss of potatoes due to decay during the whole storage period was very significant during the month of May. It is also seen from table 2 that this loss was the highest in the first fortnight of May. The loss due to decay and weight loss was significantly lower in potatoes treated with Gammexane D.034 and Geigy-33A.

Table 3 and figure 2 show the percentages of loss due to insect pests and different storage diseases. This storage loss was mostly due to tuber-moth (caused by *Phthorimea operculella*) or by dry rot (caused by *Fusarium ceruleum*).

During the storage of treated potatoes it was noted that some of the chemical formulations used in the treatments impaired the sprouting quality of tubers even though they did not completely stop the sprouting. Table 4 shows the percentage of germination in treated tubers.

Discussion

Storage of potatoes in non-refrigerated storage houses has always been considered a difficult problem. Fresh tubers have a very high rate of transpiration at ordinary atmospheric temperature during the months from April to August and Mathur (5) reported that the successful method of prolonging the life during storage has been found to be the reduction of this rate of transpiration at low temperatures. The temperatures in summer and during the spring months are so high that enormous losses in weight and decay occur in storage. Lutz (4) reported that during storage of potatoes in unrefrigerated condition, in an average storage temperature of 81.1° F., the loss caused by decay and loss in weight amounted to 35.0 and 19.6 per cent, respectively.

TABLE 1.—*Showing active ingredients and details of treatments.*

Fungicides and Insecticides, *etc.*	Active Ingredients	Treatments
1. Fusarex*	Contains 3 per cent Tetrachlor nitrobenzene	Potatoes were dusted as soon as harvested from the field at the rate of 6 ozs. per 82 lbs. of tubers.
2. Ceremul-C	50 per cent Paraffin wax as an emulsion in water	Diluted wax emulsion was prepared with 1 part Ceremul-C to 7 parts of water. The temperature of the water was kept at 70°F. The potatoes were dipped so they became completely coated.
3. Aretan*	Contains 3 per cent mercury as alkoxy alkyl mercury chloride	Half per cent solution prepared by adding the powder in water. The tubers were just dipped and dried.
4. Geigy-33A	Contains 10 per cent DDT	Potatoes were dusted evenly with the powder at the rate of 0.6 oz. per 82 lbs. of tubers.
5. Gammexane D.034	Contains 4 per cent BHC and 0.5 per cent Gammexane BHC	Tubers were dusted evenly with the powder at the rate of 0.6 oz. per 82 lbs. of potatoes.
6. Barsprout	Methyl ester of naphthaline acetic acid.	Potatoes were dusted thoroughly at the rate of 1.8 ozs. to 82 lbs. of tubers.
7. Kresvite	"	"

*By permission of Bayer Agriculture Ltd.

Sharma (8) reported that wax emulsion has been used successfully to retard the rate of transpiration of fresh fruits and vegetables. Pretreatment of potatoes in Ceremul-C, a wax emulsion, before storage, reduced the loss in weight compared with the check but the percentage of reduction of weight loss was not significant when compared with other treatments. Hall (2) found that the losses in weight of fruits and root crops were reduced by dipping them in wax emulsion.

From table 5 and figure 3 it is seen that the maximum storage loss caused by decay was the highest in the month of May at a temperature range of 96° F. to 82° F., whereas in the month of August when the maximum and minimum temperatures ranged from 83° F. to 80° F. respectively, the loss during storage was the lowest. It is apparent from the table that the temperature influences the storage loss to a great extent.

Franklin and Thompson (1) have shown that sprouting of potatoes

TABLE 2.—*Showing the loss in percentage in treated potatoes during storage*
(Average figures for three seasons, 1949-1950 to 1951-1952)

Treatments	April	May		June		July		August	Total Loss Due to Decay	Total Loss in Weight	Total
		1st Fortnight	2nd Fortnight	1st Fortnight	2nd Fortnight	1st Fortnight	2nd Fortnight				
1. Fusarex	3.70	4.70	1.88	1.56	2.20	1.25	1.25	1.56	18.10	16.90	35.00
2. Ceremul-C	5.00	7.76	3.13	2.13	1.81	1.50	1.94	1.50	24.77	23.80	48.57
3. Aretan	4.38	5.88	2.81	1.56	1.25	1.94	1.90	1.25	20.97	25.00	45.97
4. Geigy-33A	1.25	4.38	2.20	1.88	1.25	1.88	1.25	1.56	15.65	15.60	31.25
5. Gammexane D.034	1.88	4.06	2.81	2.20	1.88	1.25	1.25	1.56	16.89	13.20	30.09
6. Barsprout	2.20	7.15	4.38	1.88	1.56	1.94	1.25	1.25	21.61	15.90	37.51
7. Kresvite	3.00	8.70	4.13	2.13	1.80	1.51	1.93	1.60	24.80	23.20	48.00
8. Check (untreated)	5.03	8.80	5.62	3.69	2.81	1.94	1.25	2.25	31.39	25.50	56.89

TABLE 3.—*Showing the percentage of loss due to insect pests and diseases.*
(Average for three seasons 1949-1950 to 1951-1952)

Treatments	Percentage of Loss Due to				
	Tuber-moth	Dry Rot	Bacterial* Soft Rot	Other Diseases	Total Loss
1. Fusarex	8.00	1.50	4.60	4.00	18.10
2. Ceremul-C	8.20	5.57	6.00	5.00	24.77
3. Aretan	8.7	5.2	5.00	2.07	20.97
4. Geigy-33A	0.50	6.10	5.05	4.00	15.65
5. Gammexane D.034	0.75	5.34	5.80	5.00	16.89
6. Barsprout	8.00	6.50	4.00	3.11	21.61
7. Kresvite	8.00	7.00	5.00	4.80	24.80
8. Check (untreated)	12.05	8.04	6.20	5.10	31.39

***Erwinia carotovora* Jones.

during storage is proportional to the maturity of tubers and storage temperature. It is seen that during sprouting, the tubers lose weight very rapidly and consequently show a shrunken appearance as reported by Wittwer and Paterson (*9*).

Rao and Wittwer (*7*) used maleic hydrazide very successfully as a pre-harvest spray on green foliage for the retardation of storage sprouting.

Under unrefrigerated condition during the months of April to August, when the temperature and humidity is rather unfavorable for the storage of potatoes, Gammexane D.034 and Geigy-33A proved effective in controlling the storage decay and loss in weight. The decrease in decay loss was mainly due to the control of the potato tuber-moth (*Phthorimea operculella*) which is responsible for loss in decay in storage to the extent of 12.05 per cent.

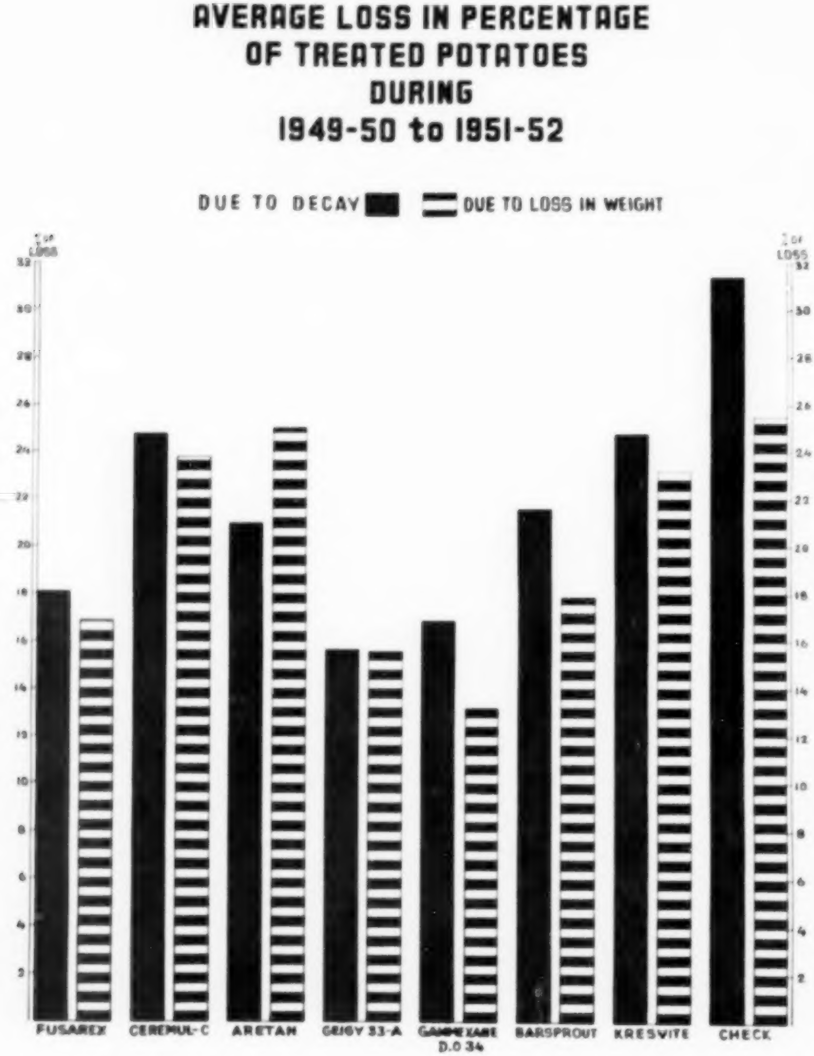

FIGURE 1.—Percentage of loss of potatoes due to decay and loss in weight.

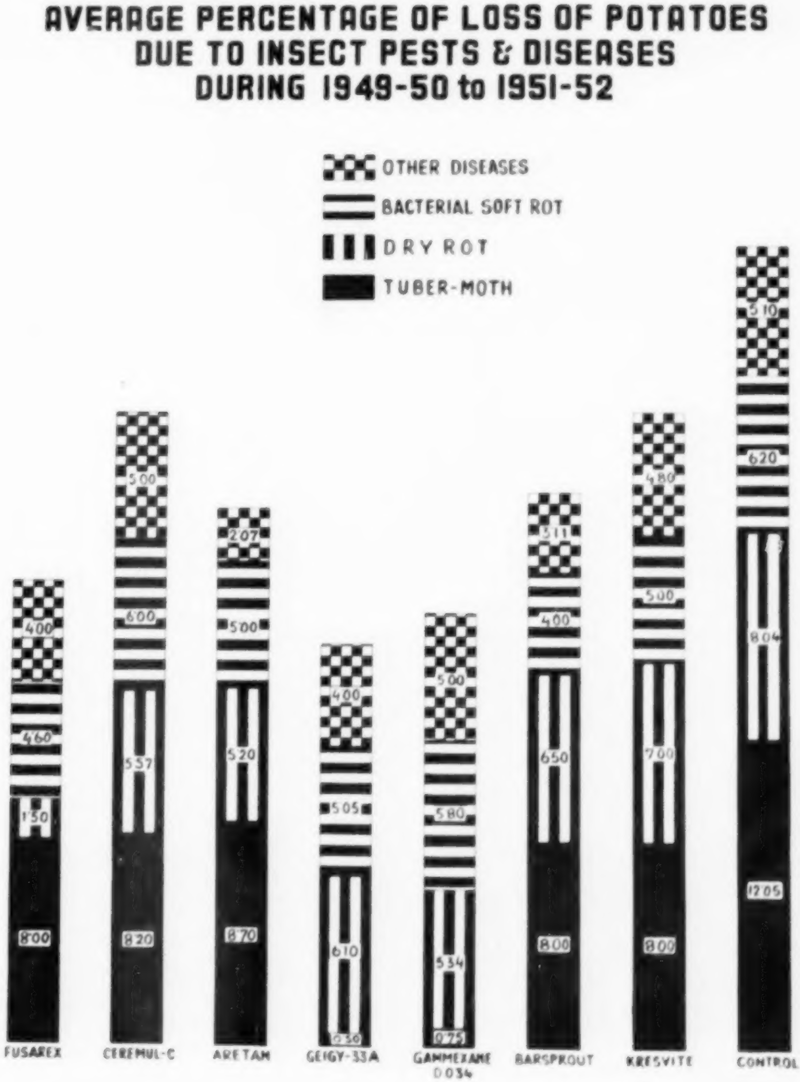

FIGURE 2.—Percentage of loss due to tuber-moth, dry rot, bacterial soft rot and other diseases.

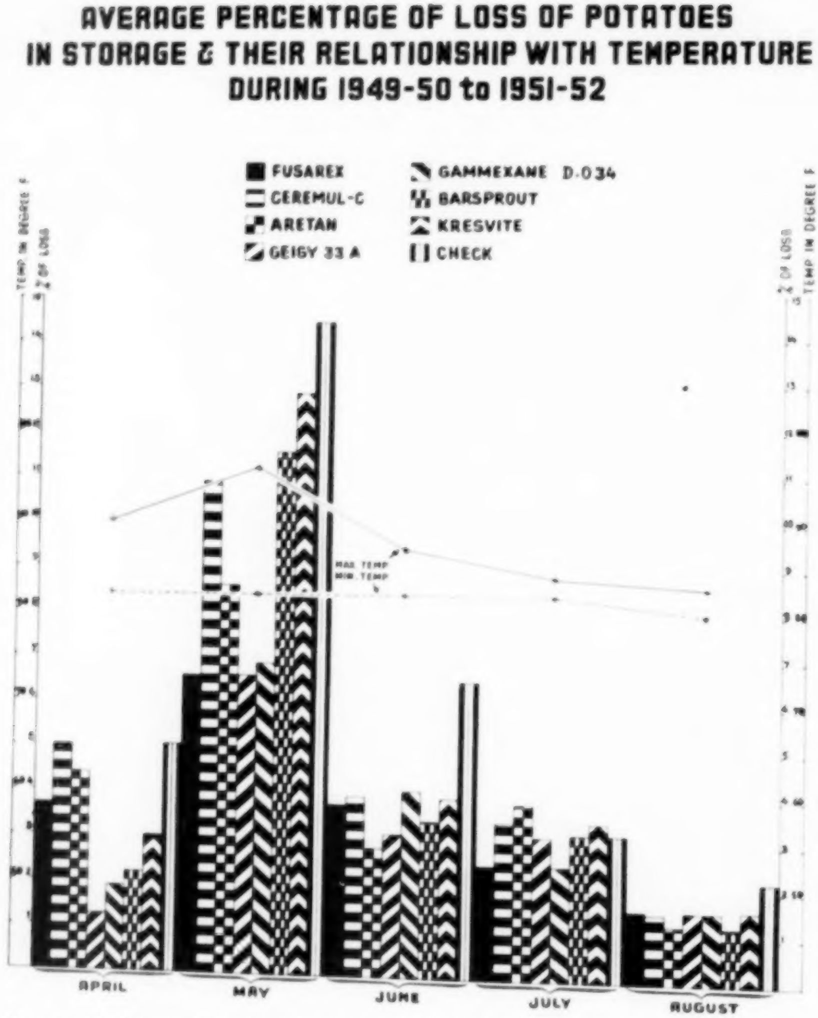

FIGURE 3.—Percentage of storage loss and its relationship with temperature in different months.

TABLE 4.—*Showing percentage of sprouted tubers after treatment.*

	April	May		June		July		August	
	Ave. Temp. 90°-80°F.	Ave. Temp. 96°-82°F.		Ave. Temp. 87°-82°F.		Ave. Temp. 84°-82°F.		Ave. Temp. 83°-80°F.	
		1st Fort-night	2nd Fort-night	1st Fort-night	2nd Fort-night	1st Fort-night	2nd Fort-night	1st Fort-night	2nd Fort-night
1. Fusarex		10.3	45.7	100.0					
2. Ceremul-C		11.7	50.3	100.0					
3. Aretan		9.9	42.0	100.0					
4. Geigy-33A		9.7	41.6	100.0					
5. Gammexane D.034		10.0	47.1	100.0					
6. Barsprout			2.5	5.5	15.8	35.3	89.7	100.0	
7. Kresvite			3.0	8.8	18.0	37.9	92.6	100.0	
8. Check (untreated)		12.0	48.3	100.0					

TABLE 5.—*Showing the losses in percentage during each month and their relationship with temperature.*

(Average figure for three seasons 1949-1950 to 1951-1952)

	April	May	June	July	August
	Average Tempera-ture	Average Tempera-ture	Average Tempera-ture	Average Tempera-ture	Average Tempera-ture
	Max. Min. 90°F. 82°F.	Max. Min. 96°F. 82°F.	Max. Min. 87°F. 82°F.	Max. Min. 84°F. 82°F.	Max. Min. 83°F. 80°F.
1. Fusarex	3.70	6.58	3.76	2.50	1.56
2. Ceremul-C	5.00	10.89	3.94	3.44	1.50
3. Aretan	4.38	8.69	2.81	3.84	1.25
4. Geigy-33A	1.25	6.58	3.13	3.13	1.56
5. Gammexane D.034	1.88	6.87	4.08	2.50	1.56
6. Barsprout	2.20	11.53	3.44	3.19	1.25
7. Kresvite	3.00	12.83	3.93	3.44	1.60
8. Check (untreated)	5.03	14.42	6.50	3.19	2.25

ACKNOWLEDGMENT

The author desires to thank Dr. H. K. Nandi, Director of Agriculture for his criticism. Thanks are also due to Mr. S. C. Pal, Research Assistant, for his assistance.

SUMMARY

1. Dusting tests have been conducted with various insecticides, fungicides, sprout-inhibiting chemicals and wax emulsion *viz.*, Gammexane-D.034, Geigy-33A, Fusarex, Barsprout, Kresvite, Ceremul-C for the control of loss in weight due to decay.

2. Under unrefrigerated conditions with a temperature range of 80°-96° F. pre-treatment of tubers with Gammexane-D.034 and Geigy-33A in proportion 0.6 ounces to 82 pounds of tubers significantly controlled the storage loss caused by decay and loss in weight.

3. Sprout-inhibiting chemicals reduced the weight loss during storage, but failed to control significantly the loss caused by decay.

Literature Cited

1. Franklin, E. W. and N. R. Thompson. 1953. Some effects of maleic hydrazide on stored potatoes. Amer. Potato Jour. 30: 289-295.
2. Hall, E. G. 1947. Food Preserve Quarterly 7: 39.
3. Kapur, N. A., P. B. Mathur and Kripal K. Singh. 1952. Accumulation of sugars in potatoes in cold storage, Bull. C.F.T.R.I., Vol. 3: 42-43.
4. Lutz, J. M. 1947. Storage of southern-grown potatoes during the summer. Amer. Potato Jour. 24: 209-220.
5. Mathur, P. B. 1951. Studies in cold storage of potatoes. Jour. Sci. Ind. Res. 10: 224-228.
6. ———— and Kripal K. Singh. 1952. Cold storage of potatoes — a practical aid to "save more" and "grow more food." Ind. Farm. 1-2.
7. Rao, S. N. and S. H. Wittwer. 1955. Further investigations on the use of maleic hydrazide as sprout inhibitor for potatoes. Amer. Potato Jour. 32: 51-59.
8. Sharma, J. N. 1936. Art of preventing decay. U.S.P. 2: 392.
9. Wittwer, S. H. and D. R. Paterson. 1951. Inhibition of sprouting and reduction of storage losses in onions, potatoes, sugar beets and vegetable root-crops by spraying plants in the field with maleic hydrazide. Mich. Agr. Exp. Sta. Quart. Bull. 34: 3-8.

BREEDING VARIETIES OF POTATO RESISTANT TO VERTICILLIUM WILT IN MAINE

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In recent years potato wilt caused by *Verticillium albo-atrum* Reinke & Berthold, has been receiving much attention in Maine. The causal fungus is soil- and seed-borne and the practice followed by many growers, especially during the days of price control, of producing potatoes year after year on the same land has resulted in the soil sometimes becoming heavily infested with it and in reduction in yield due to the early dying of the potato plants. It is possible that in the future, varieties highly resistant to verticillium wilt will be needed if a profitable crop is to be grown without adequate rotation on those heavily infested soils.

Verticillium wilt is not a new disease. It was first described in Germany in 1879 and since then has been found in most of the temperate regions of the world. It has been reported in several of the Northern States and in all the potato-growing areas of Canada (1). In 1921 McKay (3) reported that *Verticillium albo-atrum* was widely distributed in Oregon having been recorded from 16 counties. It was responsible, annually, for the failure of a number of fields to pass inspection for certification. The yields of affected plants were reduced on the average from 30 to 50 per cent.

In 1917 it was stated by M. F. Barrus that wilt caused by the fungus *Verticillium albo-atrum* showed symptoms much like Fusarium wilt and the two were very easily confused in the field (2). In Idaho Nielsen (7) found that verticillium wilt was the cause of that which the growers referred to as "early dying" of potato plants, a disease that for many years has resulted in large reduction in yields of the Russet Burbank potato. When Nielsen first observed the disease he diagnosed it, as others had done, as Fusarium wilt but after several years of careful work he stated that "early dying of potatoes in southern and eastern Idaho is primarily caused by *V. albo-atrum* R. and B."

MATERIALS AND METHODS

At the Plant Industry Station, Beltsville, Maryland, varieties with a previous history of resistance or tolerance to verticillium wilt were crossed and selfed to study the reactions of various progenies to the causal fungus. Seedlings were grown to maturity at Beltsville and one tuber of each was sent to the Chapman Farm, Maine, for increase. The following year the best selections from the progenies were grown in 5-hill rows on the Ashby farm at Caribou, Maine, where, in previous years Katahdin had shown as much as 30 per cent verticillium wilt.

In addition to the progenies, many varieties and advanced selections used as parents in the breeding program were included in the tests, and several varieties and advanced selections were tested for percentage of infection, yield, and total solids.

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Materials Tested and Results

In 1951, 193 selections from the breeding and increase plots and 282 seedlings representing 20 family lines were included in the test. Katahdin and Kennebec were planted as checks in every 10th plot throughout the field, or 37 times. Forty-nine per cent of the 37 Katahdin plots and 87 per cent of the Kennebec plots showed one or more wilted plants. More than one-half of the 193 selections from the breeding and increase plots escaped infection and 37 per cent of the seedlings in the family lines were free from wilt. Because of the relatively low percentage of wilt in the Katahdin and Kennebec checks, the results were not conclusive. However, there were significant differences among the family lines, indicating that resistance is heritable. Three of the best progenies were Katahdin selfed, Chippewa selfed, and the cross (41956 x Cherokee) x (41956 x 96-56). The resistance found in the cross is especially interesting since McLean (6) found that the variety 41956 is highly resistant to verticillium wilt in Idaho.

In 1952 the tests for verticillium wilt resistance were planted on the same field as in 1951. Five-hill plots of 186 selections from the breeding and increase plots and 496 seedlings representing 19 family lines were included. The Katahdin and Kennebec varieties again were planted as checks, this time at intervals of 50 plots. The environmental conditions in 1952 were much more favorable for infection than those of 1951. In 1952 all plots of both checks showed wilted plants. On a plant basis Katahdin was 89 per cent infected and Kennebec 97. Only 7 of the 186 selections and 10 of the 496 seedlings remained free from infection. 41956, 792-88 and 792-94, the last two from a cross of 41956 and Earlaine, showed 15 per cent infection or less and can be considered very resistant.

In 1953 the seedlings and varieties tested for resistance to verticillium wilt were planted on the same field as in previous years. A total of 312 seedlings representing 12 family lines and 31 selections from the breeding plot was included in the 5-hill row test. Kennebec, Houma, and Katahdin were planted at 50-row intervals as checks. The level of infection was less in 1953 than in 1952, despite the fact that the field had been planted to potatoes continually for 4 years. On a plant basis 86 per cent of the Kennebec, 46 per cent of the Houma, and 51 per cent of the Katahdin were wilted. Under these conditions 56 seedlings were free from the disease. Five selections of Katahdin selfed, 2 of 3 selections of Chippewa selfed, and several parents were free from infection for the second year.

The 1954 tests for verticillium wilt resistance to infection from infested soil followed the same pattern as those of former years. Five hundred eighty-seven selections from 26 family lines were included in the 5-hill row test. Katahdin, Houma, and Pungo were planted at 50-row intervals throughout the field as checks. For the second year the level of infection was lower than in previous years. In 1952 the Katahdin checks on a plant basis were 89 per cent diseased, in 1953, 51 and in 1954, 28 per cent. This decrease in percentage of wilted plants is no doubt due partly to seasonal differences. Nearly one-half of the seedlings escaped infection, but since one-third of the Katahdin plots showed no infection the results cannot be considered conclusive. However, there

seemed to be significant differences between family lines in their reactions to verticillium wilt.

No varieties have been found immune from wilt, but some varieties consistently show a low percentage of infection and others produce relatively high yields of tubers despite high levels of infection. Nine varieties of potato were tested for their reaction to verticillium wilt, yield, and percentage of solids on wilt-infested soil on the Ashby farm, Caribou, Maine, for 3 years; 13 others were tested 2 years; and 11 were tested for 1 year. The data for these tests are given in table 1. Among the varieties tested for 3 years, Ontario, 41956, 792-88, and 792-94 showed relatively low percentages of infection. The other 5 varieties were very susceptible. In the group of 13 varieties tested for 2 years the 2 varieties that showed the lowest infection were Houma with 15 per cent and Russet Burbank with 22. Two of the 11 varieties tested for 1 year, B 579-3 and B 920-7, showed 8 per cent and 2 per cent infection, respectively. In contrast to these, Triumph showed 98 per cent infection.

In each test there was a small but insignificant negative correlation between heavy infection and high yield. That the correlation was not significant was surprising, since doubtlessly wilt reduces the yield of any variety. However, some varieties produce relatively high yields despite heavy infection. Saco, with a 3-year average of 64 per cent infection, and B 355-35 with 54 per cent wilt did not yield significantly differently from Ontario with only 9 per cent.

Among the varieties tested for 2 years, Pungo with 82 per cent infection yielded the same as Houma with 15 per cent and Green Mountain with 56 per cent wilt yielded approximately 70 per cent more than Russet Burbank with 22. The inherent yielding capacity of the varieties is evident in these results.

It is logical to suppose that early dying of the plants caused by wilt would have a tendency to prevent the development of high percentages of solids in the tubers. This may be true on the average but in these tests a number of varieties produced a relatively high percentage of solids in the tubers despite the high percentages of wilted plants. Green Mountain, a variety noted for its high dry matter, produced tubers with 19.0 per cent solids despite 56 per cent wilt. 41956, 792-94, Saco, Russet Burbank, Cherokee, Mohawk, Merrimack, B 595-76, and B 606-37 produced tubers with more than 19.0 per cent solids. The percentage wilt in these 9 varieties ranged from 11 for 792-94 to 82 for Cherokee.

The wilt in the tests reported resulted from infection by soil-borne organisms, since disease-free potatoes were used in planting the plots. The fungus that causes verticillium wilt is also tuber-borne. A study was made of the percentage of wilted plants resulting from the tuber-borne fungus. In 1952 samples of approximately 20 tubers were taken at random from each of 2 replications of the yield test that was grown on the Ashby farm in wilt-infested soil. These tubers were examined for disease symptoms in the spring of 1953. The tubers showing no discoloration were classified as visibly healthy and those showing discoloration were considered diseased. All tubers were planted in wilt-free soil. The resulting plants were examined for wilt symptoms and the number of non-wilted and wilted plants are recorded in table 2.

TABLE 1.—*Percentage infection, yields*[1] *and percentage of solids*[2] *of a number of varieties of potatoes grown in verticillium wilt-infested soil on the Ashby Farm, Caribou, Maine, 1952-1954.*

Variety	Parentage	Years Tested	Mean for Years Tested		Solids
			Verticillium Wilt	Yield per Acre	
		No.	Per cent	Bus.	Per cent
Ontario	Richter's Jubel x 44537	3	9	500	17.7
41956	G.S. 9-1 x 24642	3	12	359	20.1
792-88	41956 x Earlaine	3	13	327	18.5
792-94	41956 x Earlaine	3	11	334	20.4
Katahdin	40568 x 24642	3	39	429	18.1
Irish Cobbler	———	3	61	320	17.9
Sebago	Chippewa x Katahdin	3	56	382	17.9
Saco	41956 x (96-56)	3	64	509	20.0
B 355-35	(96-56) x Saranac	3	54	477	18.4
Houma	Charles Downing x Katahdin	2	15	407	18.5
Russet Burbank	———	2	22	284	19.5
Pontiac	Triumph x Katahdin	2	57	465	16.5
Delus	Mohawk x (96-56)	2	65	319	18.8
Cherokee	(96-56) x (528-170)	2	82	342	19.3
Chippewa	40568 x 24642	2	57	401	16.9
Green Mountain	———	2	56	485	19.0
Kennebec	B 127 x (96-56)	2	68	430	17.7
Mohawk	Green Mountain x Katahdin	2	52	420	19.9
Menominee	Richter's Jubel x 44537	2	55	472	18.1
Pungo	(96-44) x (528-170)	2	82	407	18.7
Teton	45146 x Earlaine	2	58	480	18.5
Sequoia	Green Mountain x Katahdin	2	45	468	17.7
Boone	T15 x B 231-3	1	40	481	16.9
Merrimack	(96-56) x Saranac	1	58	436	19.7
Plymouth	Mohawk x (96-56)	1	88	457	18.0
Triumph	———	1	98	343	16.6
B 579-3	B 24-58 x Katahdin	1	8	330	18.4
B 595-76	41956 x Cherokee	1	61	401	20.2
B 606-37	41956 x (96-56)	1	46	517	19.1
B 920-7	B 401-3 x B 355-24	1	2	324	16.5
B 922-6	T15 x B 355-24	1	58	247	17.3
927-3	AAP-9 x Katahdin	1	66	300	18.9
B 2368-4	Pontiac x B 400-1	1	29	572	17.7

[1]U. S. No. 1 potatoes.
[2]Specific gravity of tubers converted to percentage total solids.

The percentage of wilted plants in 1952 varied with the variety from 12 per cent for 41956 to 98 per cent for Pungo. There was a corresponding range in percentages of tubers showing discolored flesh from 2.5 per cent for 41956 to 100 per cent for Pungo. The plots planted in 1953 with the visibly healthy tubers produced wilted plants ranging from 0 for some varieties to 100 per cent for others, and the same was true for the plots planted with the tubers showing discolored flesh. However, the percentage of wilted plants produced from the visibly healthy tubers was much lower than the percentage of wilted plants grown from visibly diseased tubers.

TABLE 2.—*Disease symptoms in plants and tubers of 28 varieties of potato grown in 1952 on soil infested with the wilt fungus, and the number of wilted plants produced when these tubers were planted in 1953 on soil free from the wilt-causing fungus.*

Variety	Plants Wilted 1952	Tubers Examined 1952			Plants Grown in 1953 from 1952 Tubers					
		Visibly Healthy	Visibly Diseased	Visibly Diseased	From Visibly Healthy			From Visibly Diseased		
					Healthy	Wilted	Wilted	Healthy	Wilted	Wilted
	Per cent	No.	No.	Per cent	No.	No.	Per cent	No.	No.	Per cent
41956	12	39	1	2.5	39	0	0.0	1	0	0.0
Essex	53	37	3	7.5	33	4	10.8	2	1	33.3
X792-94	14	36	4	10.0	35	1	2.8	4	0	.0
Menominee	64	33	7	17.5	22	11	33.3	5	2	40.0
Ontario	13	30	9	23.1	27	3	10.0	8	1	11.1
927-3	66	30	8	21.1	30	0	.0	5	3	37.5
Katahdin	48	27	13	32.5	25	2	7.4	7	6	46.2
Sequoia	40	26	14	35.0	26	0	.0	10	4	28.6
792-88	19	26	14	35.0	25	1	3.8	12	2	14.3
Saco	74	25	15	37.5	20	5	20.0	13	2	13.3
Russet Burbank	35	25	15	37.5	25	0	.0	14	1	6.7
Chippewa	56	23	17	42.5	22	1	4.3	7	10	58.8
Triumph	98	23	17	42.5	9	14	60.9	9	8	47.1
B 447-98	90	19	21	52.5	17	2	10.5	9	12	57.1
Green Mountain	67	17	23	57.5	15	2	11.8	23	0	.0
Erie	58	16	24	60.0	14	2	12.5	20	4	16.7
Russet Rural	54	13	27	67.5	11	2	15.4	14	13	48.1
B 595-76	61	11	29	72.5	10	1	9.1	12	17	58.6
Teton	74	8	29	78.4	6	2	25.0	13	16	55.2
Irish Cobbler	96	7	33	82.5	0	7	100.0	7	26	78.8
Mohawk	69	6	34	85.0	6	0	.0	27	7	20.6
Kennebec	82	4	34	89.5	0	4	100.0	4	30	88.2
B 355-35	73	4	36	90.0	3	1	25.0	32	4	11.1
Merrimack	74	3	36	92.3	3	0	.0	31	5	13.9
Plymouth	88	3	37	92.5	2	1	33.3	10	27	73.0
Sebago	71	3	35	92.1	2	1	33.3	15	20	57.1
Cherokee	88	1	39	97.5	0	1	100.0	0	39	100.0
Pungo	98	0	40	100.0	0	0	.0	0	40	100.0

A total of 1,109 tubers from 28 varieties was examined. Of these 495 were apparently healthy and 614 showed brown discoloration in the flesh. Of the plants grown from the 495 tubers that were apparently healthy, about 14 per cent wilted and nearly 49 per cent of the 614 visibly diseased tubers produced wilted plants.

Discussion and Summary

Verticillium wilt, often referred to as "early dying," has been taking a toll for many years from potato growers in the temperate regions of North America. The fungus causing this disease is soil- and tuber-borne and no satisfactory method of control has been found.

Roguing is not very effective since the fungus spreads from plant to plant during the growing season (4). The spread of the fungus from one plant to another apparently takes place under ground through root contacts. Many potato plants contaminated from adjoining plants do not show wilt symptoms in the field probably because of late infection, and so roguing the visibly wilted plants does not control the disease effectively.

The wilt-producing fungus is carried in the tubers, often causing discoloration in the flesh, but the presence of discoloration cannot be relied upon exclusively in separating diseased from healthy tubers for seed purposes. The present study shows that tubers with no visible discoloration when planted on wilt-free soil may produce wilted plants. However, a higher percentage of wilted plants were produced from tubers showing discoloration in flesh than from visibly healthy tubers.

Growing potatoes year after year on the same soil is presumed to increase wilt in succeeding crops, but such increase does not always occur. In 1951, 13 per cent of the Katahdin check plants were wilted; in 1952, 89 per cent; in 1953, 51 and in 1954, 28 per cent. The decreases in the severity of the epidemics from 1952 on were found despite the fact that each year the refuse from the wilted plants was left on the ground and incorporated in the soil.

Rotation of crops has been recommended as a means of controlling verticillium wilt, but results vary with the location. In Oregon (5) a crop rotation including clover for 2 years preceding potatoes largely eliminated the wilt fungus from infested soils. In Idaho (7) the pathogen survived 7 years in soils cropped with barley and alfalfa.

Growth regulators have been used in Connecticut (8) in attempts to control verticillium wilt. These regulators were employed in fields in which the soil was infested with the causal fungus. Of several treatments tested only one, an early foliage spray with a high concentration of a growth regulator, gave a reduction in wilt. The reduction was significant in two fields and small in the third field, and no reduction occurred in the fourth field. The treatment partially controlled the disease but caused from 17 to 25 per cent reduction in yield in 3 fields and a non-significant increase in yield in the fourth field.

Since all control measures devised, thus far, are only partially effective, the production of resistant varieties is a necessity. Hundreds of seedlings and many varieties both foreign and domestic were tested. There were significant differences between progenies of crosses and

between selfed lines in their reaction to the wilt fungus indicating that resistance is heritable. Differences are also found among the advanced selections and named varieties. Seedling variety 41956 and its derivatives, such as *792-88* and *792-94*, are highly resistant. Ontario and Menominee, two sister varieties, are resistant, but Menominee seems to become more heavily infected in Maine than it does in Idaho (6).

Some varieties produce satisfactory yields despite heavy infections. Insignificant negative correlations were found between heavy infections and high yields. In this respect the results in northern Maine differ from those obtained in Idaho between heavy infections and high yields where highly significant negative correlations were found consistently.

With all the differences prevailing among seedlings and varieties it should be possible to breed, in a relatively short time, a high-yielding, high-quality variety of potato, highly resistant to, if not immune from, verticillium wilt.

Literature Cited

1. Ayers, G. W. and D. B. Robinson. 1953. Verticillium wilt of potatoes and its control. Dept. of Agr., Ottawa, Canada, Publication 888: 1-6.
2. Gilbert, Arthur W. (Assisted by Mortier F. Barrus and Daniel Dean). 1917. The potato. The MacMillan Co., New York. (318 Pp.)
3. McKay, M. B. 1921. Transmission of some wilt diseases in seed potatoes. Jour. Agr. Res. 31: 821-848.
4. ————. 1926. Potato wilt and its control. Oreg. Agr. Exp. Sta. Bull. 221 (23 Pp.)
5. ————. 1926. Furrther studies of potato wilt caused by *Verticillium albo-atrum*. Jour. Agr. Res. 32: 437-470.
6. McLean, John G. 1955. Selecting and breeding potatoes for field resistance to verticillium wilt in Idaho. Idaho Agr. Exp. Sta. Bull. (In press.)
7. Nielsen, L. W. 1948. Verticillium wilt of potatoes in Idaho. Agr. Exp. Sta. Res. Bull. 13: (23 Pp.)
8. Waggoner, Paul E. and Gordon S. Taylor. 1955. Experiments in the control of verticillium wilt of potatoes in Connecticut in 1954. Amer. Potato Jour. 32: 168-172.

THE RESPONSE OF IRISH POTATOES TO DIFFERENT AMOUNTS AND RATIOS OF NITROGEN, PHOSPHORIC ACID AND POTASH WHEN GROWN IN CONTINUOUS CULTURE.[1]

T. E. Odland and J. E. Sheehan[2]

The question of what kind and amount of fertilizer to use for the most economical returns in potato growing is an ever recurring one. As the fertility status of the soil changes due to the cropping program the fertilizer must be adjusted accordingly. Heavy fertilizer applications for potatoes are the usual practice, especially in the northeastern states. In Rhode Island the commercial potato growers usually specialize in the one crop so that potatoes are grown year after year on the same land. Very often this results in large accumulations of both available phosphorus and exchangeable potassium in the soil. Unless the fertilizer used is adjusted to meet the changing conditions much loss of efficiency will result. Many potato growers in the state are probably using too much of the wrong grade of fertilizer for potatoes to secure the best results.

The experiments described in this paper were begun in order to get inforn. ation on what modifications in the amount and kind of fertilizer should be made by the potato grower who specializes in this crop, in order to obtain the most economical returns.

Considerable work has been done on potato fertilizers at the Rhode Island Experiment Station as well as by nearly all other states in the Northeast. Results from experiments have been reported in a number of previous publications from the Rhode Island Agricultural Experiment Station (*2,5*). As a result of these experiments it was concluded that 2000 to 2500 pounds of a 6-8-8 or similar ratio fertilizer should be used for soils continuously in potatoes. Albritten *et al* (1) reported on fertilizer application studies on several potato farms in Rhode Island. Little response to phosphorus or potash was found on old potato fields that had received heavy fertilizer applications over a period of years. It was concluded that a 6-8-8 or similar fertilizer would be more suitable under those conditions than the 6-12-12 that was most commonly used. Hawkins *et al* (*3*) obtained maximum yields of potatoes with 80 to 120 pounds of P_2O_5 and 100 to 120 pounds of K_2O on soils in Maine that had a high content of readily available phosphorus and exchangeable potassium. On the basis of many potato fertilizer trials in Maine, Terman and Hawkins (*6*) concluded that a 2-3-3 ratio fertilizer such as 8-12-12 or 6-9-9 applied in amounts that would supply 120 pounds of N and 180 pounds each of P_2O_5 and K_2O per acre would be more satisfactory on most soils than any of the fertilizers then in use by the farmers in Aroostook County. In Connecticut, Hawkins and Brown (*4*) recommend 2100 pounds per acre of 7-7-7 or 1500 pounds of a 10-10-10 fertilizer for soils high in P and K where potatoes are grown continuously.

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Description of Experiment

The area used for this experiment is located on the "Peckham Farm" of the Rhode Island Station, Kingston. The soil is classified as Bridgehampton silt loam and has a pH of approximately 5.2. The soil was in a high state of fertility when the experiment was begun.

In the study of rates of fertilizer application, a standard 6-12-12 grade in amounts ranging from 1250 to 2500 pounds per acre was used during the period 1945 through 1950 as shown in table 1. In 1951 this was changed to an 8-12-12 grade and the amounts reduced to the range of 1000 to 2250 pounds per acre. Beginning in 1950, 200 pounds of Cyanamid per acre were applied to the cover crop in the spring before plowing.

In the ratio study the nitrogen was varied from 60 to 120 pounds per acre for the period 1945-1950 as is revealed in table 2. Beginning in 1951 the range was changed to vary from 90 to 150 pounds per acre. The P_2O_5 range was from 90 to 225 pounds per acre throughout the entire period and the K_2O ranged from 135 to 270 pounds per acre. Cyanamid at the rate of 200 pounds per acre was applied to all plots beginning in 1950.

Each treatment in both phases of the experiment consisted of 4 rows 275 feet long. The two center rows were harvested for yield. In 1951 the plots were split crosswise and one-half was put into a rotation of 2 years red top and 2 years potatoes. The other half remained in continuous potatoes. The yields reported are based on this half since 1951. Each treatment has four replicates in randomized arrangement. The potatoes were planted in rows 3 feet apart with the seed pieces spaced 10-12 inches in the row.

Green Mountain potatoes were used during the first 9 years of the experiment. In 1954 the variety used was changed to Katahdin. The fertilizer was applied in bands at planting time. At harvest time the total yield per acre, the yield of U.S. No. 1 and specific gravity of tubers were determined. Samples were kept in storage for determination of keeping quality.

Results

The yields of potatoes obtained in these experiments varied considerably from year to year. When the season was favorable, with rainfall well distributed, the yields were very satisfactory. The years with such favorable growing conditions were 1945, 1946, 1947, 1950, 1951 and 1953. Lack of moisture at some critical period of the growing season in 1948, 1949 and 1952 resulted in lowered yields. The 1954 season was marked by excessive rainfall and a hurricane occurring on August 31. The high winds and salt spray which accompanied the hurricane destroyed all potato vines and thus shortened the growing season.

The yields obtained with the various amounts of a standard fertilizer are presented in table 1. The lower application, 1250 pounds of a 6-12-12 or 1000 pounds of an 8-12-12 per acre, generally resulted in the lowest yield. The 10-year average was 310 bushels of U.S. No. 1 potatoes per acre. The highest average yield, over the period, 339 bushels per acre, resulted from an application of 2250 pounds of 6-12-12 or 2000 of 8-12-12. A difference of 16 bushels per acre is required for significance.

TABLE 1—*Yields of potatoes with different amounts of fertilizer at the Rhode Island Agricultural Experiment Station, 1945-1954.*

Lbs/A 6-12-12*	Yield of U.S. No. 1 Potatoes in Bushels per Acre										Average	
	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	1945-1950	1945-1954
1250	348	394	381	251	206	359	373	213	357	214	323	310
1500	343	415	412	269	192	366	386	212	376	198	333	317
1750	348	437	389	287	213	356	384	231	386	272	338	330
2000	364	461	438	282	231	383	360	194	370	257	360	334
2250	357	470	412	293	219	396	383	210	383	269	358	339
2500	338	492	402	292	221	391	345	183	366	292	356	332
Least Significant Difference, 5 per cent level.											16	16

*Beginning in 1951 the fertilizer was changed to an 8-12-12 grade and all amounts decreased by 250 pounds per acre. Beginning in 1950, 200 pounds per acre of calcium cyanamide were applied to the rye cover crop before plowing in the spring.

TABLE 2.—*Yields of potatoes with different fertilizer ratios at the Rhode Island Agricultural Experiment Station, 1945-1954.*

Treatment	Pounds per Acre			Yield of U.S. No. 1 Potatoes in Bushels per Acre										Average	
	N	P_2O_5	K_2O	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	1945-50	1945-54
Low N	60	180	180	336	364	361	234	168	339	357	186	395	242	300	298
Med. N*	90	180	180	357	412	397	272	206	378	261	188	357	260	337	319
High N	120	180	180	362	463	428	276	213	390	364	182	338	260	355	328
Low P_2O_5	90	90	180	355	402	383	252	187	351	386	152	344	185	322	300
Med. "	90	135	180	344	424	379	241	183	347	385	172	326	248	320	305
High "	90	225	180	344	438	403	261	194	348	358	148	360	246	331	310
Low K_2O	90	180	135	350	399	405	267	204	367	370	168	340	227	332	310
Med "	90	180	225	345	428	401	263	189	355	363	164	343	229	330	308
High "	90	180	270	343	407	390	255	198	362	352	150	333	240	326	303
Least Significant Difference, 5 per cent level.														12	15

*This is the equivalent of 1500 pounds per acre of a 6-12-12 fertilizer. Beginning in 1951 the N amounts were raised to 90, 120 and 150 pounds, respectively on the low, medium and high N ratios. Beginning in 1950 an application of 200 pounds per acre of calcium cyanamide were applied to the rye cover crop before plowing in the spring.

In considering the results for the various ratios of fertilizer ingredients as shown in table 2, the same fluctuation in yields from year to year can be seen. During the first six years when the amounts of nitrogen varied from 60 to 120 pounds per acre there was a significant increase in yield with each increase in nitrogen application. When the nitrogen was increased by 30 pounds in each of the low, medium and high treatments, the differences became less. The use of 200 pounds per acre of Cyanamid on the cover crop doubtless accounts in part for the lesser response to nitrogen during the past 4 years. As an average for the 10 years there was a significant increase for the medium over the low nitrogen treatment but not for the high nitrogen over the medium. At the 5 per cent level, 15 bushels per acre are required for significance in the fertilizer ratio phase.

Four levels of P_2O_5 were compared with applications of 90, 135, 180 and 225 pounds per acre. The nitrogen and potash were kept constant at 90 pounds of N and 180 pounds of K_2O per acre. A significant increase in yield was obtained when the P_2O_5 application was increased from 90 or 135 pounds to 180 pounds per acre. No further increase in yield resulted when the P_2O_5 application was increased to 225 pounds per acre.

The K_2O levels compared were 135, 180, 225 and 270 pounds per acre with N and P_2O_5 kept constant at 90 and 180 pounds per acre respectively. Increasing the K_2O application from 135 to 180 pounds per acre resulted in increasing the average yield from 310 to 319 bushels per acre. This difference is not large enough to be significant. When the application was increased to 270 pounds per acre there was a significant decrease in average yield when compared with the 180-pound rate.

Specific gravity determinations were made on the potatoes harvested from all plots during the last four years of the experiment. No consistent differences were found in the phase where different fertilizer ratios were used. In the amounts phase there was a small gradual decrease in specific gravity of the tubers as the amounts of fertilizer applied were increased from 1000 to 2250 pounds per acre of an 8-12-12 grade. The specific gravity of the tubers ranged from 1.069 with the 1000-pound application to 1.061 with 2250 pounds of fertilizer.

No differences in keeping quality as judged by the amount of shrinkage of samples or in sprouting at the end of storage was noted among the different lots.

Discussion

The area selected for this experiment was typical of many potato farms in Rhode Island. As a result of continued use of heavy applications of fertilizer for potatoes, large reserves of P_2O_5 and K_2O had accumulated in the soil. This in turn resulted in little or no yield response to these fertilizer nutrients beyond 180 pounds of each per acre. When a grower continues using a ton or more of a 6-12-12 or similar fertilizer for potatoes he is applying at least a third more of these nutrients than his crop can profitably use.

The response to nitrogen increases in the fertilizer was positive and fairly constant when the nitrogen was increased from 60 to 120 pounds per acre. When the nitrogen was increased to 150 pounds per acre there was no further increase in yields. Since 40 pounds per acre of nitrogen were applied to the cover crop in the spring, the actual amount of the nitrogen

range beginning in 1951 was 130 to 190 pounds per acre. The response to nitrogen during the first six years of the experiment had shown that the 60- and 90-pound rates were insufficient. The rates were therefore increased so that the lowest rate became 90 pounds in addition to the spring application of 40 pounds N in calcium cyanamide. The results since 1951 indicate that a total of 130 to 160 pounds of nitrogen, including both the cover crop application and that applied at planting time, is sufficient for the average crop.

When different amounts of a 6-12-12 fertilizer were used there was a consistent response up to 2000 pounds per acre but no further increase in yield beyond this amount. No increase in yield was obtained by the use of more than 1750 pounds of an 8-12-12. This test indicates that the potato grower could obtain entirely satisfactory yields of potatoes when grown in continuous culture by using less of a better balanced fertilizer than is now commonly used.

From these results it would seem that a potato grower should gradually change from a 1-2-2 ratio to one approaching a 1-1-1 after he has been growing his crop under continuous culture for a number of years. He can also reduce the amounts of total fertilizer used. An application of 1500 to 2000 pounds per acre of an 8-12-12 or 10-10-10, depending on his local soil conditions, is probably as much fertilizer as his crop can use to advantage. If a less concentrated fertilizer, such as a 6-8-8 is used, the amount would need to be increased to a range from 2000 to 2500 pounds.

Summary

In these experiments various amounts of either a 6-12-12 or an 8-12-12 fertilizer were compared as well as a standard amount of different grades having various ratios of N, P and K.

Green Mountain and Katahdin varieties were used, yields were determined and data on specific gravity and keeping qualities obtained. The experimental area had been used for growing potatoes for a number of years previous to the beginning of the experiment and was in a high state of fertility.

Little response to increasing the application of P_2O_5 or K_2O above the minimum used was obtained. There was a consistent increase in yield resulting from increased nitrogen applications up to about 120-130 pounds per acre. Only relatively small differences in specific gravity of the tubers or in keeping quality was noted as resulting from the different fertilizer treatments. No significant increase in yield resulted from using more than 2000 pounds per acre of a 6-12-12 grade or 1750 pounds of an 8-12-12 per acre.

Continuous potato culture with heavy applications of fertilizer results in accumulations of P_2O_5 and K_2O in the soil. The fertilizer grade and amount needs to be adjusted accordingly in order to obtain the most economical return.

It is concluded that under these conditions the ratio of N, P and K in the fertilizer should be gradually changed from the customary 1-2-2 to one approaching a 1-1-1 ratio for continuous potato culture. An application of 1500 to 2000 pounds per acre of an 8-12-12, 10-10-10 or similar fertilizer will probably supply all the nutrients needed by the potato crop.

Literature Cited

1. Allbritten, H. G., T. E. Odland and M. Salomon. 1951. Nutrient status of soils on commercial potato producing areas in Rhode Island. Soil Sci. Soc. Amer. Proc. 15:248-251.
2. Bell, R. S., T. E. Odland and A. L. Owens. 1949. A half century of crop rotation experiments. R. I. Agr. Exp. Sta. Bull. 303.
3. Hawkins, Arthur, J. A. Chucka, and A. J. MacKenzie. 1947. Fertility status of potato soils of Aroostook County, Maine and relation to fertilizer and rotation practices. Maine Agr. Exp. Sta. Bull. 454.
4. ———— and B. A. Brown. 1949. Fertilizer recommendations for potatoes in Connecticut. Mimeo Circ. Univ. of Conn. Feb.
5. Odland, T. E., R. S. Bell, and D. A. Schallock. 1951. Potato growing in Rhode Island. R. I. Agr. Exp. Sta. Bull. 310.
6. Terman, G. L. and Arthur Hawkins. 1947. Fertilizing potatoes economically in Aroostook County, Maine. Better Crops with Plant Food. 31: 23-26, 41-44.

POTATO FLAKES. A NEW FORM OF DEHYDRATED MASHED POTATOES REVIEW OF PILOT PLANT PROCESS[1]

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The purpose of this paper is to review the pilot-plant process for making a new form of dehydrated mashed potato which we have termed "potato flakes." In earlier papers we have described the operation of the double drum drier to produce this product (1), and also discussed in some detail the factors influencing the texture of the reconstituted product (2). A brief summary of these findings and some more recent developments will be included here.

Several forms of dehydrated mashed potatoes are already well-known. The potato granule, which is primarily unicellular in form, has been made by several methods (3). Other physical forms (including a shred and a hollow cylinder) have been made by various extrusion processes. The flake process has an inherent advantage in that it is an easily controlled, direct drying process utilizing familiar drying equipment. Problems of control of appearance and flavor are minimized because the potatoes are ready for drying immediately after mashing and the entire dehydration is accomplished in less than half a minute. A desirable subtle baked potato flavor is imparted during the short drying process.

The process described here is one in which the double drum drier was used. Recent work on a single drum drier of the type normally used in the production of potato flour has indicated its suitability for the flake process.

PILOT PLANT PROCESS

Raw potatoes are abrasive peeled, hand-trimmed and sliced into ⅝ inch thick slices. A pre-cooking step, a newly discovered method of control of texture, is then interposed after which the slices are finally cooked, usually in steam. The cooked slices are mashed immediately and diluted with a small amount of hot water to adjust the solids content and thereby improve adherence to the rolls of the drier. Sulfite salts or other additives may be easily incorporated during this step. The mash is applied to the drums and dehydrated under conditions of temperature time and roll clearance to yield a product of excellent quality at the required dryness. The product is removed from each drum as a thin continuous sheet of controlled thickness which is then broken and screened to yield flakes of the desired size.

RAW MATERIAL — CONTROL OF TEXTURE

Good appearance and flavor are essential requirements in a mashed potato but they are less difficult to achieve in a dehydrated product than the important attribute of good texture. A desirable product is one which

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has texture as near that of freshly mashed potato as possible. Preferences will vary geographically from smooth or creamy to mealy, but it must never be lumpy, pasty or gummy. By preventing cell rupture, both during manufacture and during rehydration, the release of free starch is minimized and pastiness is avoided. However, a low solids potato, even though processed with little cell damage will still not yield an acceptable mashed potato texture due to the insufficient amount of starch contained in the potato cells.

Idaho Russet Burbanks are predominately used in making dehydrated mashed potatoes. High solids varieties have heretofore always been necessary in making dehydrated mashed potatoes to obtain good texture on reconstitution. In the flake process, however, the precooking step enables the use of several varieties of lower solids content. Katahdin, Kennebec and Cobblers grown in the East have been used to make a product of excellent quality.

Precooking

By the use of a two-stage cooking method, the texture of mashed potatoes reconstituted from potato flakes can now be varied as desired from smooth, through mealy, to excessively grainy. The method consists of a precook at a temperature high enough to gelatinize the starch, preferably in the range from 150° F. to 165° F. followed by a final cook at 212° F. The ⅝ inch thick raw slices usually require from 15 to 30 minutes precooking in either water or steam-air mixture.

After the precooking treatment, the slices are no longer crisp, as when raw but are tougher, resilient, and somewhat translucent. After the final cooking in steam the slices are still tougher than those not precooked and when mashed yield a drier appearing, more mealy mash. The exact choice of conditions is determined by the type potato being processed and the texture desired in the reconstituted product. In general, the lower the precooking temperature (within the range cited) the more mealy the product. Also, as the precooking time is increased, the effect becomes more apparent. Experimental work has shown that precook temperatures below 150° F. or holding times of an hour produced too large a particle size in the mash to give an acceptable product. Obviously the shortest cook is the most economical. This is 15 minutes generally at about 160° F.

Although an understanding of the effects of precooking on product texture has been gained, further work is required to explain them. Studies regarding the nature of the changes taking place are in progress. Most investigations so far indicate that a modification of the starch within the cells resulting in an increased swelling power is the main factor. One fact which bears out this promise is the increased amount of liquid necessary for rehydration of flakes made by precooking to produce a typical mash. This may be 5.0:1 or even 5.25:1 compared to 4.5:1 for potatoes which were not precooked.

Cooking and Mashing

The shortest permissible cooking time for ⅝ inch thick slices is about 16 minutes in atmospheric steam. Precooked slices given this treatment are tough and rubbery and cannot be mashed between rolls. An extrusion

type masher in which the potatoes are forced through holes of approximately 1/16 inch diameter produces a mash which can be dried either on a single or double drum drier.

Drying

Feeding.

If a mass of mashed potato is placed between the rolls af a 6-inch diameter double drum drier, the type used for our investigation, there will be practically no pickup on the rolls.

To obtain a uniform sheet on both drums the mash in the "V" must be kept in motion with an action which wipes it on the drum surfaces. This results in a thin film adhering to the hot surface before the drums converge at the pinch, and the rough surfaces thus created aid the acceptance at the pinch. This motion is accomplished in the pilot plant by manipulation of the mash with a paddle, but it can be simulated mechanically. It is expected that when a drier of larger diameter is used, the increased area of pinch resulting from the lesser angle of approach will aid the feeding of the mash. With a single drum the mash is applied the same way as in making potato flour—by spreader rolls placed about the periphery of the drying surface.

Roll Clearance.

With a double drum unit the clearance between the rolls has been found to be optimum in the range that produces films of substantially monocellular thickness. If the clearance is too small the individual potato cells are crushed and the flake reconstitutes to a pasty product. If the clearance is too large, the cells adhere in agglomerates, resulting in a product of high moisture content which may also be lumpy. In practice, a flake thickness of 0.005 inch to 0.009 inch produced with a drum clearance of about 0.007 inch to 0.010 inch is preferred. It has been demonstrated that a good product can also be made on a single drum unit of the type commonly used for potato flour. The condition for best operation are still being studied.

Dilution of Mash.

Dilution of the mash from high solids (above 20 per cent) potato prior to drying results in several improvements in the product. Among these are higher flake density, *i.e.*, more cells and less voids per unit area, and a greater resistance of the flake to shattering during breaking to the desired size. Both density and strength increase as high solids mash is diluted with water, reaching a maximum when the solids content has been reduced to approximately 20 per cent, and diminishing on further dilution.

Another important result of dilution is better adherence to the drum and lower product moisture for a given drying condition. Low moisture in the flake avoids too rapid rehyration thereby minimizing cell rupture and producing a better textured mash. Normally a flake moisture varying between 3 and 4 per cent is achieved when the drier is operated at 100 p.s.i. steam pressure with a residence time of roughly 10 seconds.

Additives

A solution of sulfite salts is used to lighten the color of the product and increase storage stability. Three parts of sodium sulfite to one part sodium bisulfite used as a 10 per cent solution has proven satisfactory. When incorporated in the mash prior to drying at the rate of 400 parts per million of sulfur dioxide about 200 parts per million are retained in the dried product. No detectable taste is imparted at this level.

Flake Size

The product of the drum drier is removed from each drum as a thin continuous sheet the full width of the drum. These sheets must be broken into flakes of a convenient size for packaging. When they are broken, cleavage occurs not only between the cells but through them as well, therefore some free starch is released at the periphery of the flake. If the flake is large the broken cells are insignificant compared with the number of undamaged cells in the flake. As the pieces become smaller the ratio of peripheral cells to enclosed cells increases and a size is eventually reached where a degradation in texture can be detected.

Many samples of potato flakes have been prepared and distributed to demonstrate the product. These have been made up of flakes ranging in sizes from 3/16 inch to 5/8 inch, having a package density of nearly 7 pounds per cubic foot. This relatively low density should be advantageous in the civilian market where the consumer is interested in "more for the money." In flakes of this size the amount of free starch is insignificant and contributes no noticeable pastiness to the reconstituted product. Recent work with precooked potatoes has shown, however, that flakes can be made as small as 7-mesh or about ⅛ inch without objectionable increase in pastiness on reconstitution. Flakes of this size have a bulk density of about 11 pounds per cubic foot and hence can be packaged more cheaply.

Potato flakes rehydrate easily on addition of water at temperatures ranging from 50° F. to boiling. Usually 4.5 to 5.25 parts of liquid at about 160° F. are used. This temperature is conveniently achieved by mixing 3 parts of boiling water with 1 part of cold milk. The liquid is poured over the flakes until the entire mass is moistened. Butter and salt are added to taste and the product lightly whipped if a creamy consistency is desired.

Work completed shows that flakes capable of being reconstituted to mashed potato of excellent texture, color and flavor can be made by that which appears to be a comparatively cheap process, on readily available and commonly used equipment.

Literature Cited

1. Cording, James, Jr., Miles J. Willard, Jr., Roderick K. Eskew, and Paul W. Edwards. 1954. Potato flakes. A new form of dehydrated mashed potatoes. I. Pilot-plant process using double drum drier. U.S. Dept. Agr., Agr. Res. Serv. Circ. ARS-73-2.
2. ———, ———, ———, and ———. 1955. Potato flakes. A new form of dehydrated mashed potatoes. II. Some factors influencing texture. U. S. Dept. Agr., Agr. Res. Serv. Circ. ARS-73-9.
3. Olson, R. L. and W. O. Harrington. 1951. Dehydrated mashed potatoes—A review. U.S. Dept. Agr., Bur. of Agr. and Indus. Chem. AIC-297, January.

NEWS AND REVIEWS

ANNOUNCEMENT OF ANNUAL MEETING

The 40th Annual Meeting of The Potato Association of America will be held in conjunction with The American Phytopathological Society on December 6, 7, and 8 at the Plaza Hotel, Cincinnati, Ohio. Details regarding submission of papers and registration will be announced later.

USDA ISSUES REPORT ON POTATO FUTURES MARKETING INVESTIGATION

The U. S. Department of Agriculture recently released a 200-page report by the Commodity Exchange Authority on speculation, hedging, and price fluctuations in potato futures on the New York Mercantile Exchange in the 1954-55 season.

The report covers the CEA investigation which was begun last spring in view of heavy speculation and sharp price fluctuations in potato futures, and presents information and statistical data on 1954-55 trading and the general character of the futures market for Maine potatoes. The report also summarizes interviews with Maine potato growers, dealers, and others, and the results of CEA compliance work.

Roger R. Kauffman, CEA administrator, said that in spite of trading abuses requiring disciplinary proceedings for violation of the Commodity Exchange Act, analysis of the potato futures show indications of economic utility in the pricing and marketing of Maine potatoes.

He said cash potatoes in Maine are often priced on the basis of futures, but many members of the Maine potato industry, including a majority of growers interviewed, expressed dissatisfaction with futures trading on grounds of speculative losses and sharp price fluctuations. It was found, however, that a considerable number of Maine dealers and shippers and some growers have used the market effectively for hedging—in most cases by sales of futures to offset risks of price declines on anticipated production and on stocks of cash potatoes.

The report shows that in many respects futures trading in potatoes is similar to that in other futures markets. Speculative trading in potato futures accounted for a large part of the total volume, open contracts tended to follow a seasonal pattern, and deliveries on futures contracts amounted to only about 1 per cent of trading volume. Numerous small speculators, who bought on balance as hedgers sold, accounted for the greater part of the long side of the market. Large traders—25 carlots and over—predominated on the short side.

"A striking difference compared with other futures markets," Mr. Kauffman said, "has been the withdrawal of hedging positions before the marketing of the bulk of the Maine potato crop in the late winter and spring, leaving the market largely speculative.

"The reports show that the New York market has been used extensively in the planting and growing season by dealers and growers who make hedging sales to diminish price risks incident to forward contracting and the extension of credit against anticipated production," the CEA administrator pointed out. "But the hedging volume has dropped sharply

each year after harvest, although the bulk of Maine potatoes, carrying heavy price risks, normally remains unmarketed until late winter and spring.

"With hedging participation greatly reduced last winter and spring, the market became predominantly speculative at the critical marketing period, and highly susceptible to speculative pressures and erratic price fluctuations," Mr. Kauffman continued.

The CEA report showed that the trading volume in New York potato futures reached a record 200,000 carlots in the year ended May 31, 1955. The average for the past three years, amounting to 130,000 carlots, was 10 times the average for the 7 years preceding.

The potato futures volume over the past three years ranged from 1 to 3 times the size of the Maine crop, compared with a trading volume in wheat futures for the same period ranging from 3 to 4 times production, cotton 3 to 5 times, and soybeans 11 to 22 times.

The number of traders in New York potato futures ranged from 1,154 on November 30, 1954, to 725 on February 28, 1955. This compares with 4,498 traders in the major wheat futures market, in corn 4,317, oats 6,884, soybeans 4,392, and cotton 3,447, as of the dates of the most recent surveys of these markets.

Traders in Maine and New York held the bulk of the open contracts in potato futures. The report showed that, in effect, Maine was on the long side of the potato futures market and New York on the short side.

A substantial part of large traders' positions in potato futures were short hedging commitments during the planting and growing season, reaching a peak in October 1954, near the end of harvest. But hedging commitments declined to much lower levels in the winter months, although large Maine potato stocks remained unmarketed, with attendant price risks.

As hedging participation declined in the winter of 1954-55, large traders' speculative positions increased and became a larger part of the total market. Such speculative positions, long on balance during most of the growing season, and in the fall about equally divided long and short, became heavily net short on balance from December 1954 through February 1955, when potato prices were weak. In March, April, and May 1955, when potato prices were higher, large traders' speculative commitments were again about evenly divided long and short.

The report also summarizes compliance work of the CEA in the 1954-55 potato futures market, including administrative complaints charging price manipulation or attempted manipulation in violation of the Commodity Exchange Act, with resultant denial of trading privileges to 13 respondents.

Administrator Kauffman said the report is designed to provide useful information on the potato futures market, particularly to growers, shippers, and others concerned with relationships between futures trading and the pricing and marketing of cash potatoes.

Single copies of the report, which is entitled "Futures Trading in Potatoes, 1954-55," may be obtained by request to the Commodity Exchange Authority, U. S. Department of Agriculture, Washington 25, D. C.

FAULTY POTATO STORAGE CAN RUIN CHIPPING POSSIBILITIES CHIP INSTITUTE RESEARCH CHIEF DECLARES

Good potato storage should prevent large accumulation of sugars and other constituents which result in dark colored chips—a factor most undesirable to chippers—Dr. Ora Smith, research director for The National Potato Chip Institute states in a pamphlet recently published by the chip association.

"It is exceedingly important," states Dr. Smith, "to have available some method of storing potatoes at 50° to 60° F. but with little or no sprout growth, no accumulation of sugars and a minimum loss of weight."

The Institute's research director emphasizes that farm or other storage structures adapted to potatoes destined for the fresh market are usually not the best for chip potatoes. It may take seven to eight months before chippers can process potatoes harvested and stored in September and October.

Titled "Potato Chips Can Be Ruined By Faulty Potato Storage", the pamphlet points out that the chip industry used 36 million bushels of potatoes last year. This will approximate 12 per cent of the total crop. The leaflet is the second in a series to meet the increased interest of Growers in the requirements of the chip industry.

Dr. Smith discusses the use of sprout inhibitors, conditions necessary during storage, floor ventilating and unloading ducts, conditions to be considered during transit and the reconditioning of potatoes for chipping.

The leaflet can be obtained by writing The National Potato Chip Institute, 946 Hanna Building, Cleveland 15, Ohio.

USDA REPORTS FOOD MARKETING COSTS UP

In line with his December 11 statement of concern covering rising food marketing costs, Secretary of Agriculture Ezra Taft Benson recently released a special USDA report, "Marketing Costs for Food." The report summarizes recent trends in food marketing costs and in the distribution of the consumer's food dollar.

Secretary Benson noted that the spread between farm and retail prices of food has increased 83 per cent since 1945. This, the report says, has been a primary factor in the decline in the farmer's share of the consumer's food dollar from a record high of 53 per cent in 1945 to an average of 41 per cent in 1955.

The report says the spread has widened primarily because of the substantial increase in all costs of performing marketing services since 1945. Wage rates are up almost 100 per cent over 1945, freight rates and other costs—packaging material, containers, fuel, equipment, rents, etc.—are up about two-thirds. State and local property taxes have increased substantially. Actual labor costs have not increased as fast as wage rates, because output per man-hour has increased according to the report.

As a percentage of the sales dollar, profits of food marketing firms have shown no marked trend in recent years. The report shows that profits of a group of large food processors, wholesale distributors, and

retail food chains have grown substantially since 1945. This increase has been due primarily to the increased volume of food sales handled by these firms.

Citing the report, Secretary Benson said the Nation's food marketing bill increased from 9 billion dollars in 1940 to 32 billion dollars in 1955. Several factors accounted for the 23-billion dollar increase. They include:

(1) The 40 per cent increase in the volume of food handled accounts for 4 billion dollars of the increase.

(2) The general rise in all prices and costs has roughly doubled the charges for performing marketing operations. This accounts for 13 billion dollars of the increase.

(3) Payments for marketing services that did not exist in 1940 account for 6 billion dollars of the increase.

Copies of the report, "Marketing Costs For Food," Miscellaneous Publication No. 708 are available from the Office of Information, U. S. Department of Agriculture, Mashington 25, D. C.